

Sex and hermaphroditism in the Penna model

Lecture "Computer Simulation": D.Stauffer

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1 Comparing sex and hermaphroditism

I compared sexual(SX) and hermaphroditic(HA) reproduction schemes within the Penna model[1]. A fixed set of parameters was used, to make the results comparable with recent simulations[2]. I also reproduced the results for a self-emerging dominance[2] in an independant simulation for both hermaphroditic and sexual cases. A variation on partner selection was also implemented, this shifted stable population sizes slightly.

The stable population is considered the most significant result for these comparisons since Stauffer et al.[3] gave strong argument, that from two species competing for the same resources the one with a higher stable population while not competing will prevail, while the other one will die out.

The parameters were: Birthrate $B = 4$, minimum reproduction age $R = 8$, mutational threshold $T = 3$, and mutation rate $M = 1$. Different values for N_{max} have been simulated. The starting population was choosen to $N(0) = N_{max}/100$.

In order to get better statistics several runs have been made with a different seed value for the random number generator, when computer time was available.

2 Constant dominance

To take the effect of dominant and recessive genes into account, a dominance 32 bit long string was generated for the whole population with $d = 6$ randomly set bits. Deletrious mutations only take effect if either both genome strings have the according bit set or one string has it set and the bit is marked as dominant by the dominance string.

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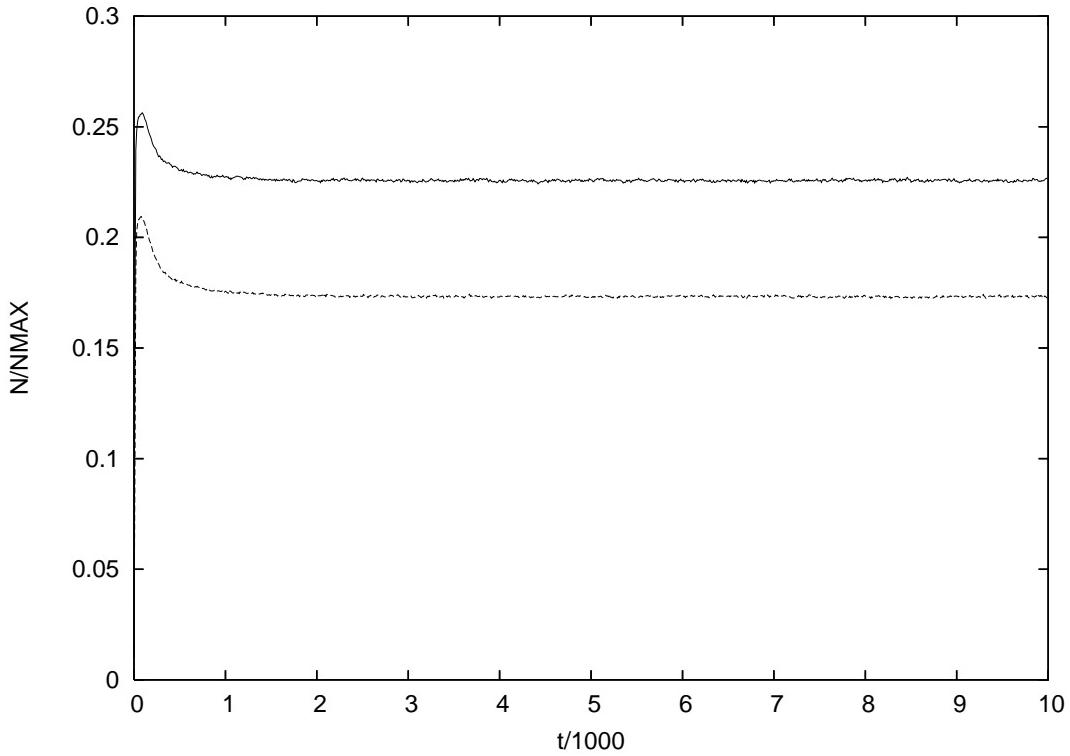


Figure 1: Comparing sexual (top curve) and hermaphroditic (bottom curve) reproduction schemes. The dominance was assumed to be constant for the whole population for these simulations.

As can be seen in table 2 the hermaphroditic populations consistently reached a stable population of $N_0/N_{max} \approx 0.23$ whereas the sexually reproducing populations reached $N_0/N_{max} \approx 0.17$. No significant difference was found for longer simulation time or larger populations.

SX/HA	N_{max}	N_{runs}	Time	N_0/N_{max}
HA	$5 \cdot 10^5$	1	$5 \cdot 10^4$	0.226
HA	$5 \cdot 10^5$	10	$1 \cdot 10^4$	0.226
SX	$5 \cdot 10^5$	1	$5 \cdot 10^4$	0.174
SX	$5 \cdot 10^5$	10	$1 \cdot 10^4$	0.173

Figure 2: Comparing sexual(SX) and hermaphroditic(HA) reproduction

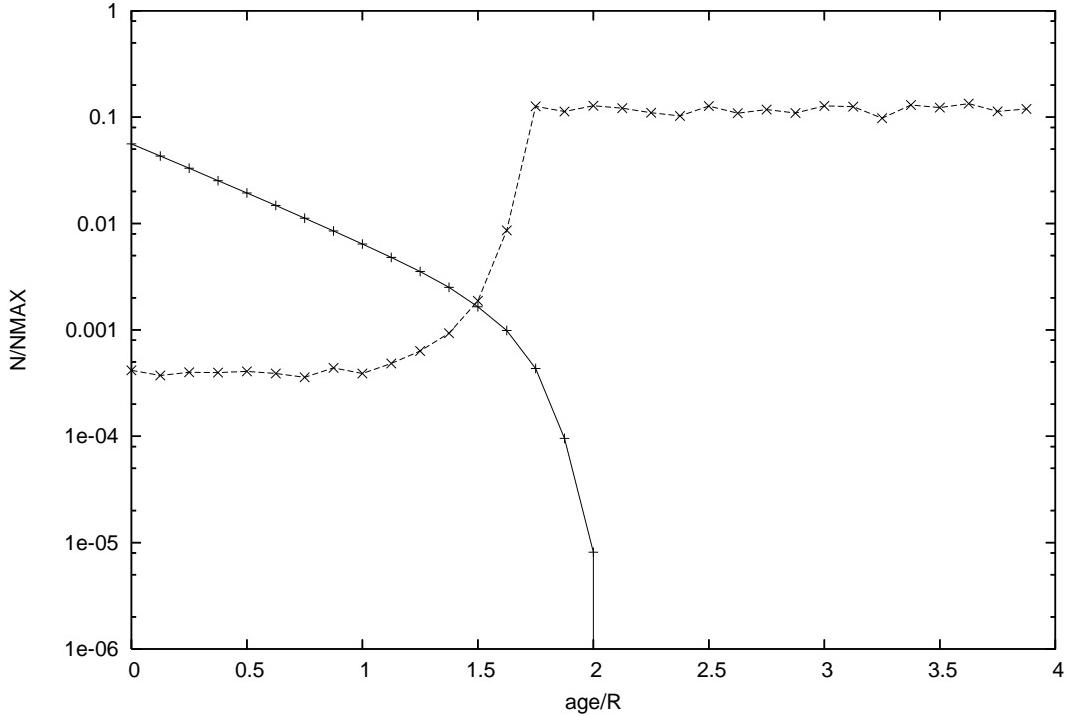


Figure 3: (x) is the number individuals with a dominance bit set at that age, (+) is the total number of individuals at that age (H,J, $N_0 \approx 0.23$)

3 Dominance self emergence

I started from the standard Penna model with sexual and hermaphroditic reproduction. Each individual now has a dominance bit string attached. With every reproduction one bit in this string is flipped with a probability of $p = 0.01$. This dominance string is then used to determine the activity of a deleterious mutation just as in the constant dominance model. As in recent simulations[2] the number dominant bits n_{dom} reached a stable value after $t \geq 10^5$ time steps (figure 6) and has an age distribution reflecting the selection pressure gradient (figure 3).

3.1 Partner selection style

In recent simulations[3] each female or hermaphroditic individual with $age \geq R$ tries to find a fitting partner from the whole population 20 times. If no partner is found, the individual chooses to not reproduce that time step. The simulations with this reproduction style are marked 20T.

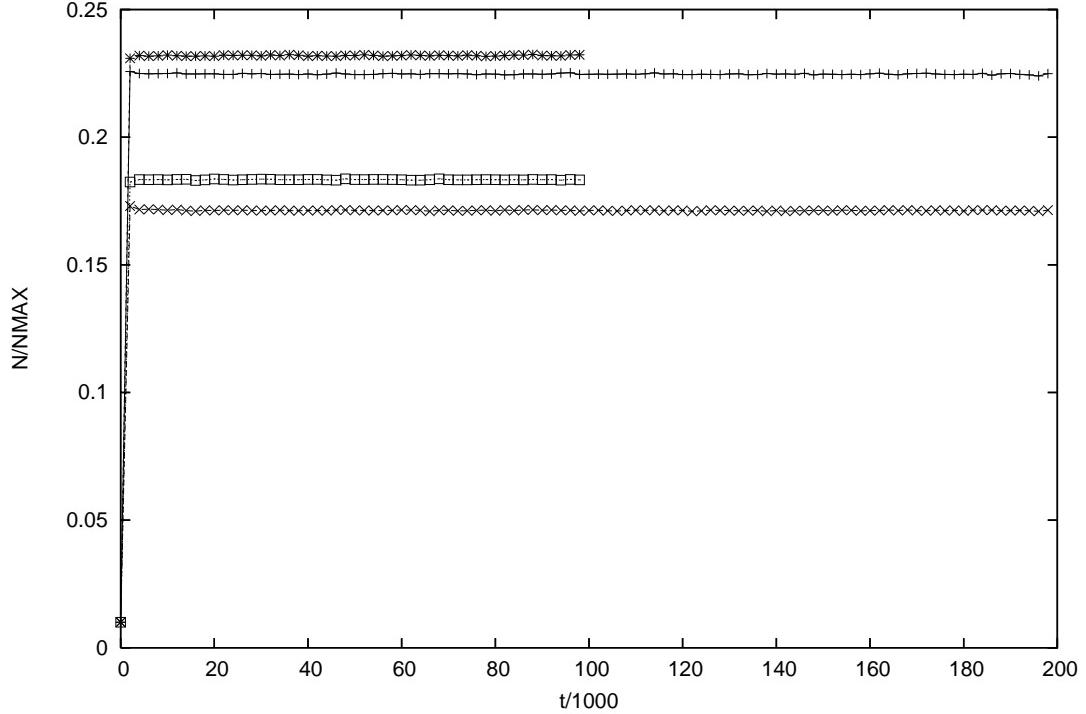


Figure 4: From top to bottom: a.) Hermaphroditic reproduction, J c.) Hermaphroditic reproduction, 20T b.) Sexual reproduction, J d.) Sexual reproduction, 20T

SX/HA	N_{max}	N_{runs}	Part.sel.	Time	N/N_{max}	n_{dom}
SX	10^7	10	20T	$2 \cdot 10^5$	0.17	8.5
SX	$5 \cdot 10^5$	50	20T	$2 \cdot 10^5$	0.17	8.2
HA	$5 \cdot 10^5$	50	20T	$2 \cdot 10^5$	0.23	8.46
HA	$5 \cdot 10^5$	50	J	10^5	0.23	9.27
SX	$5 \cdot 10^5$	50	J	10^5	0.18	8.35

Figure 5: Dominance emergence simulation parameters and results

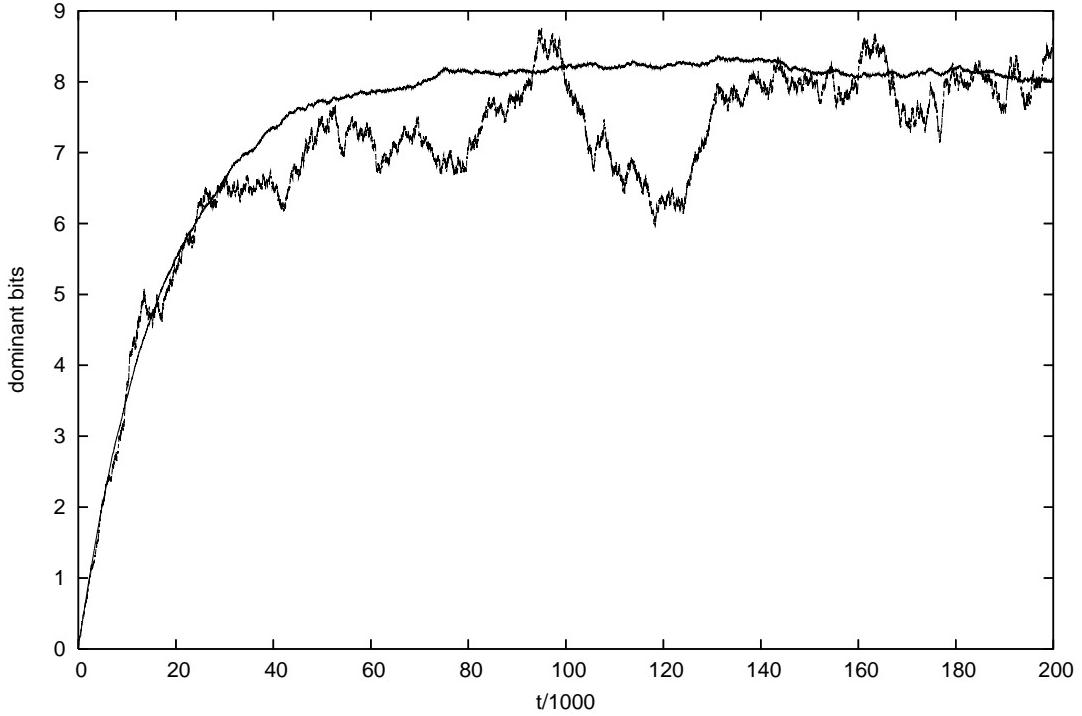


Figure 6: Number of dominant bits averaged over the whole population. The fluctuating curve represents one run, whereas the smooth curve results from averaging over 50 runs. (SX,20T)

Another model was simulated, where each turn a pool of males in the appropriate reproduction age is generated. Each female chooses one from this pool and removes it from this pool. So the individuals form couples each turn. This model is marked as J according to a german saying that each jacket will find fitting trousers.

However this different partner selection style only increased the stable population sizes slightly.

3.2 Population

As can be seen in figure 4 in the hermaphroditic case a stable population of $N_0/N_{max} \approx 0.23$ was reached, whereas the sexual reproduction scheme reached $N_0/N_{max} \approx 0.17$, The different partner selection styles simulated did not produce important differences.

4 Summary

All simulations consistently showed that hermaphroditism reaches a higher stable population size than sexual reproduction. The Penna model thus does not explain the evidence found in nature that sexual reproduction offers severe benefits over hermaphroditic reproduction. This known feature of the Penna model has been confirmed.

Several researchers have tried to give an explanation for sexual reproduction in comparison to asexual reproduction. Other reproduction schemes (especially meiotic parthenogenesis) have also been analysed. See chapter 2.5.5 in *Evolution, Money, War and Computers* by Oliviera, Oliviera and Stauffer [5].

To further compare reproduction schemes one should investigate the applicability of these approaches to hermaphroditism.

4.1 References

- [1] Penna, A bit-string model for biological aging.
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- [2] Garncarz, Cebrat, Stauffer and Blindert, Why are diploid genomes widespread?
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